



Figure 1. The trail left by the Chelyabinsk bolide. The left part of the image shows two contrarotating vortices formed by heating and buoyancy effects in the horizontal cylinder of air in which kinetic energy of the asteroid was deposited. The asteroid had a diameter of only 18 m yet produced a blast wave in the atmosphere that damaged thousands of buildings and caused injuries to some 1500 people. The high altitude of the airburst (> 20 km) and the shallow entry angle (about 17° from the horizon) combined to prevent a potentially far worse outcome. (Credit: Nikita Plekhanov; Wikimedia Commons.)

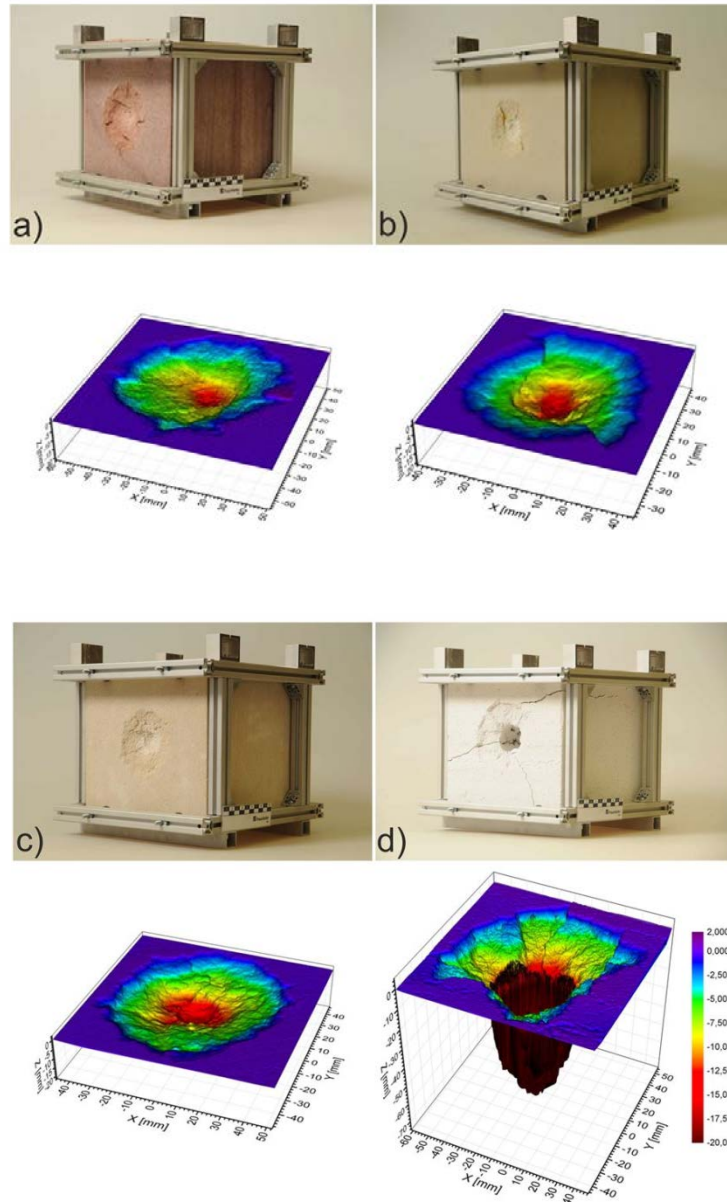


Figure 2a. Examples of the results of gas-gun experiments on asteroid surface analog materials carried out by NEOShield partner Fraunhofer Ernst Mach Institute, Freiburg, Germany. The impact craters in different target materials with porosities, ϕ , were formed by projectiles with approximately the same impact velocity: a. Quartzite ($\phi \sim 3 \%$); b. sandstone ($\phi \sim 25 \%$); c. limestone ($\phi \sim 31 \%$); d. aerated concrete ($\phi \sim 87 \%$). In each case a photograph of the target after the impact is shown above a three-dimensional model of the crater morphology. The colour code shown adjacent to the bottom right crater model applies to all four models. The experiments demonstrate that large craters are formed in highly porous material but in contrast, the ejected mass is small. (Credit: Fraunhofer EMI.)

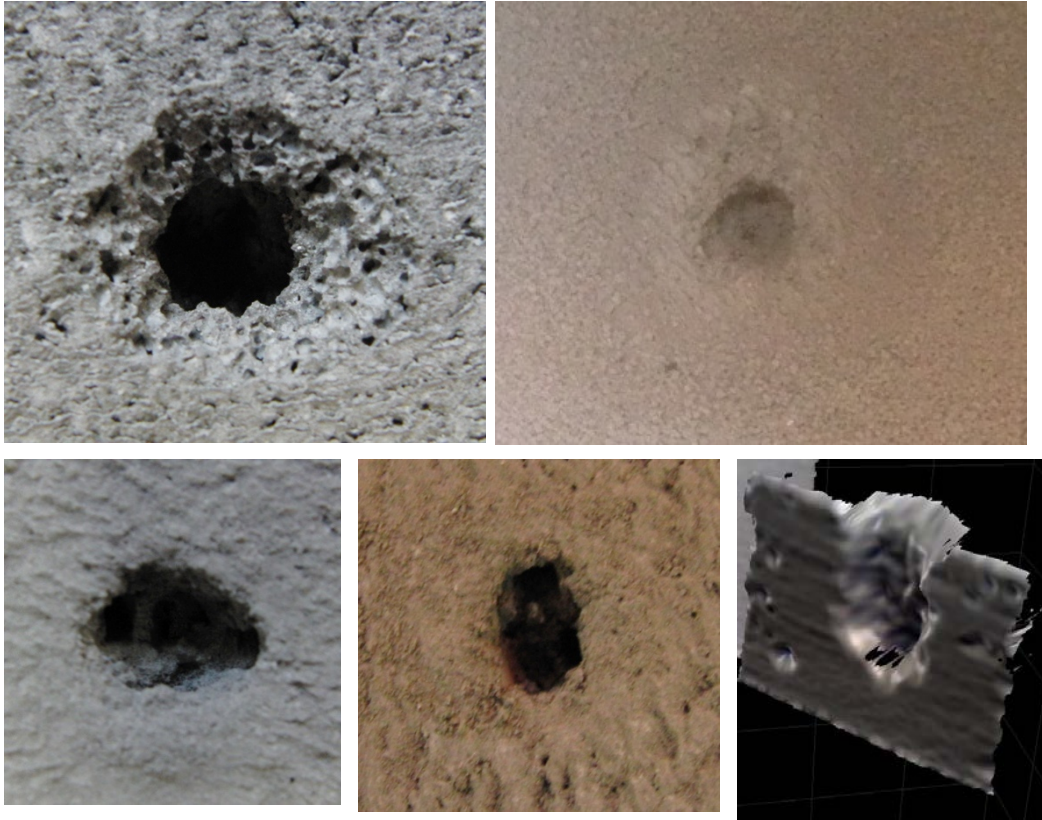


Figure 2b. Examples of the results of experiments with the all-angle gas gun operated by NEOShield partner Open University. The frames show craters in solid aerated concrete (top left), and with 5 mm (top right), 10 mm (lower left) and 20 mm (lower centre) overlying layers of regolith. Lower right: scan of the cross-section of the top left hand crater showing large depth/diameter ratio. The depth of the core crater is smaller for impacts with a regolith layer present but, for the small data set available, does not change with increasing regolith layer depth. This is true for regolith layers at least as thick as the crater depth in the solid target, indicating that particles penetrate much deeper in the regolith than they do in the solid. (Credit: Open University.)

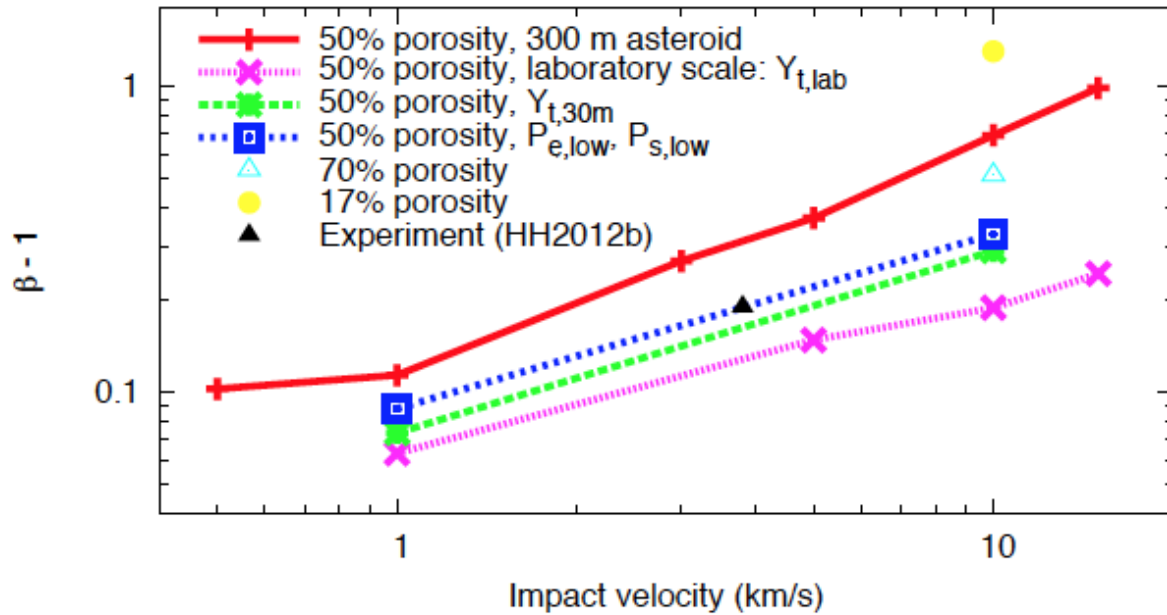


Figure 3. Momentum multiplication factor $\beta-1$ as a function of impact velocity, considering various strengths and porosities. The result of an impact experiment using a pumice target (Housen and Holsapple, 2012) is also shown. High tensile strengths, Y_t , corresponding to a 30 m ($Y_{t,30m}$) and a 3 cm ($Y_{t,lab}$) sized body, lead to less ejecta and therefore a smaller β . On the other hand, using a lower crushing strength (i.e., smaller crush-curve parameters P_e , P_s) leads to more compaction and therefore also less ejecta and smaller β . Increasing the porosity, while keeping the strength parameters constant, leads to a decreased β . Overall, our results are in reasonable agreement with the laboratory measurements of β in the case of a porous pumice target (Housen and Holsapple, 2012, 43rd LPSC, LPI Contribution No. 1659). Figure from Jutzi and Michel, 2014, Icarus 229:247-253.

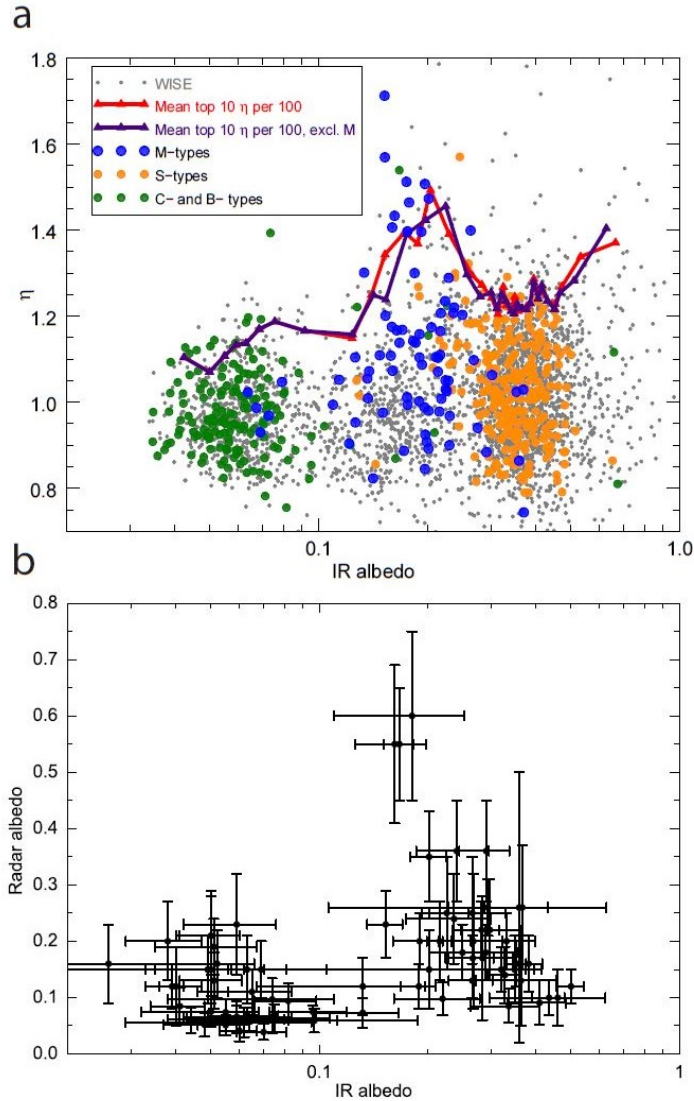


Figure 4.

a. WISE η values versus infrared albedo. η is a model fitting parameter derived by finding the model thermal continuum that best fits the measured infrared fluxes of a NEO; in general, η increases with thermal conductivity. Basic taxonomic types are shown as coloured bullets. The red curve is a plot of the mean of the highest 10 η values in bins of 100 data points; the purple curve is the same after removal of all the currently identified and suspected M (metallic) types from the dataset. The fact that the peak persists implies that many more metallic asteroids exist but remain unidentified to date.

b. Radar albedo versus WISE near-infrared albedo for main-belt asteroids. The broad clustering into 3 groups seen in (a) is also evident here, whereby the central group here corresponds to high radar albedo, and in (a) to a peak in η and the location of the M types.

Figure from Harris and Drube, 2014, Ap.J. Letters, 785:L4.



NEOSshield mission target selection lists



Rendezvous targets			Fly-by targets		
Selected	All (Delta-v)	All (Name)	Selected	All (Delta-v)	All (Name)

All NEOs with Rendezvous delta-v < 6 km/sec, ordered by delta-v

Colour	MPC Orbital Uncertainty Code
White	0 - 1
Green	2 - 3
Orange	4 - 6

Warnings: CEU is an RMS uncertainty, the error ellipse may be significantly larger along the major axis.
Numbers in brackets () are inferred from other parameters and have not been directly measured.

	Number	Name	H	delta-v (km/s)	U (MPC)	CEU (")	D (km)	a/b	Albedo	Taxonomy	Period (hr)	Tumbling?	Binary?	PHA?
1		2006RH120	29.5	3.94	1	8.4		3.0			0.0458;0.03			
2		2012TF79	27.4	3.94	3	165								
3		2009BD	28.1	3.95	0	1.65	0.004		.45					
4		2010UE51	28.3	4.00	2	96								
5		2007UN12	28.7	4.00	3	246								
6		2008HU4	28.2	4.02	3	570								
7		2010VQ98	28.2	4.09	3	129								
8		2013XY20	25.5	4.12	3	60								
9		2012EC	23.4	4.13	2	39								
10		2013DA1	27.3	4.13	6	1470								
11		2008EA9	27.7	4.13	5	810								
12		1991VG	28.5	4.18	2	273								
13		2013EC20	29.0	4.20	5	135								
14		2012WR10	28.7	4.24	5	510								
15		2013BS45	25.9	4.25	0	2.4								
16		2014SU1	25.0	4.26	4	87								
17		2010AN61	27.0	4.26	5	14700								

Figure 5. Screenshot of the first 17 entries in the target selection list, here in order of increasing rendezvous dv for NEOs likely to be in the size range ~ 100 m to ~ 600 m. The total number of entries at the time of writing was 1163. The online list, which was updated regularly during the course of the project with new NEO discoveries and measurements of physical parameters, is currently located at http://star.pst.qub.ac.uk/~af/lowdv_neos/. (Credit: Queen's University, Belfast).

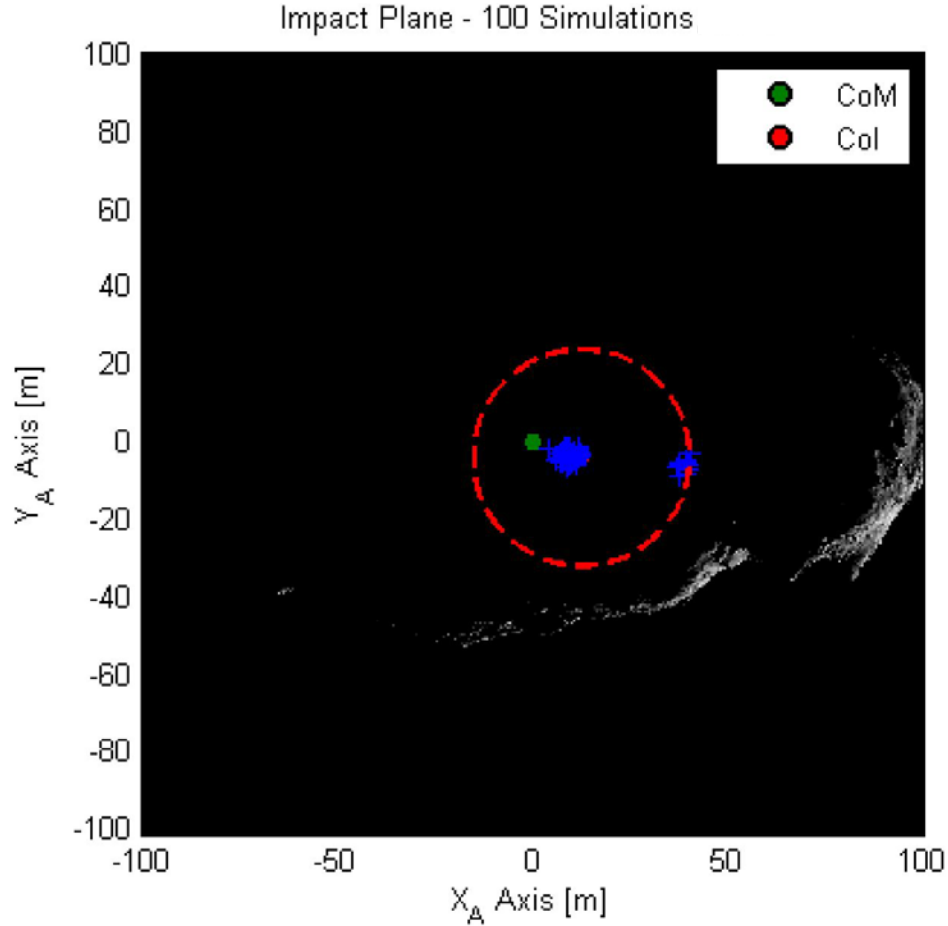


Figure 6. The results of 100 simulated impacts of a kinetic impactor into the NEO 2001 QC₃₄. Note that due to the very high phase angle at impact (roughly 140 degrees), only a very small sunlit horizon of the asteroid is visible. The last measurement and manoeuvre were 100 s prior to impact. The shape of the NEO Itokawa was assumed since the shape of 2001 QC₃₄ is unknown. The largest diameter of the ellipsoid was taken to be 190 m, which was computed to be the smallest possible value given current knowledge and pessimistic uncertainty assumptions. The smallest diameter of the ellipsoid is around 100 m. A larger area would reduce the risk of missing the target and enhance the quality of the information provided by the vision-based navigation. The green bullet is the center of mass (CoM) of the asteroid, chosen as the reference target point. The red-dashed circle is a projection onto the image of the navigation error standard deviation envelope. The blue crosses are the individual points of impact of each of the 100 Monte Carlo runs. The red dot (just visible at the edge of the main cluster of blue crosses) is the averaged point of impact (centre of Impact, CoI). For most (~ 85%) of the impacts the performance is very good (within 12 m), with only a very small bias of some 5 - 7 m in the direction of the centre of brightness (CoB). The remaining 15% of impacts fell in a tight cluster 40 m away in the direction of the CoB, suggesting that the timing of the final measurement and manoeuvre (100 s before impact) may require revision. A preliminary investigation considered a last manoeuvre at 50 s prior to impact instead of 100 s which increased the performance by a factor of 2 and reduced the number of offset points from 15% to 3%. The overall performance of the system is well within the goal and commensurate with analytical expectations. See Deliverable 8.2 for further details.

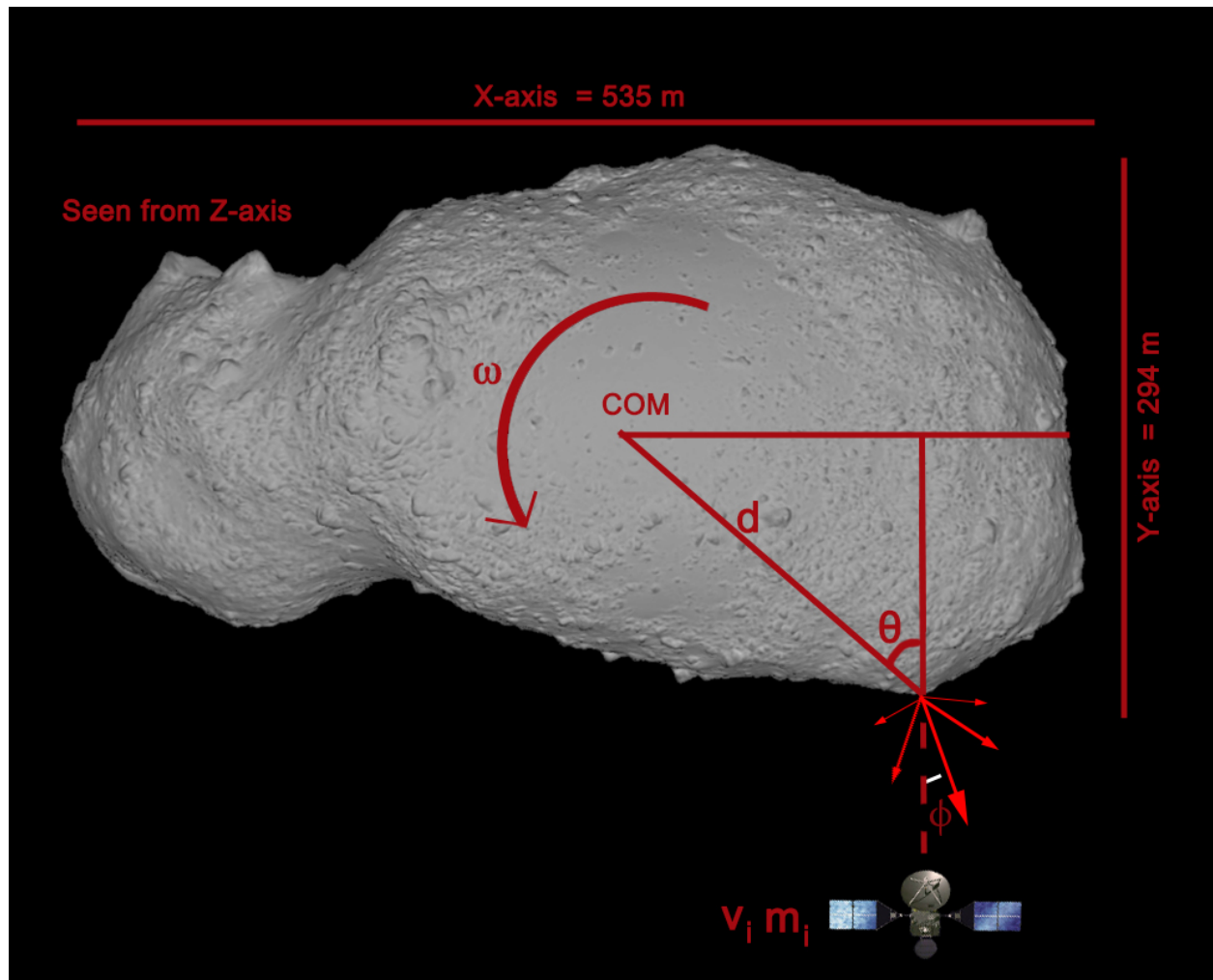


Figure 7. A kinetic impactor impacts off-center on Itokawa thereby changing its rotational period. Itokawa's dimensions are 535 x 294 x 209 m and it rotates around the Z-axis, which is perpendicular to the image. See Deliverable 9.6b for further details. Credit: Robert Gaskell produced the shape-model of Itokawa used.



Figure 8. Artist's impression of NEO deflection by means of a gravity tractor (from Deliverable 8.3, background image credit: ESO).

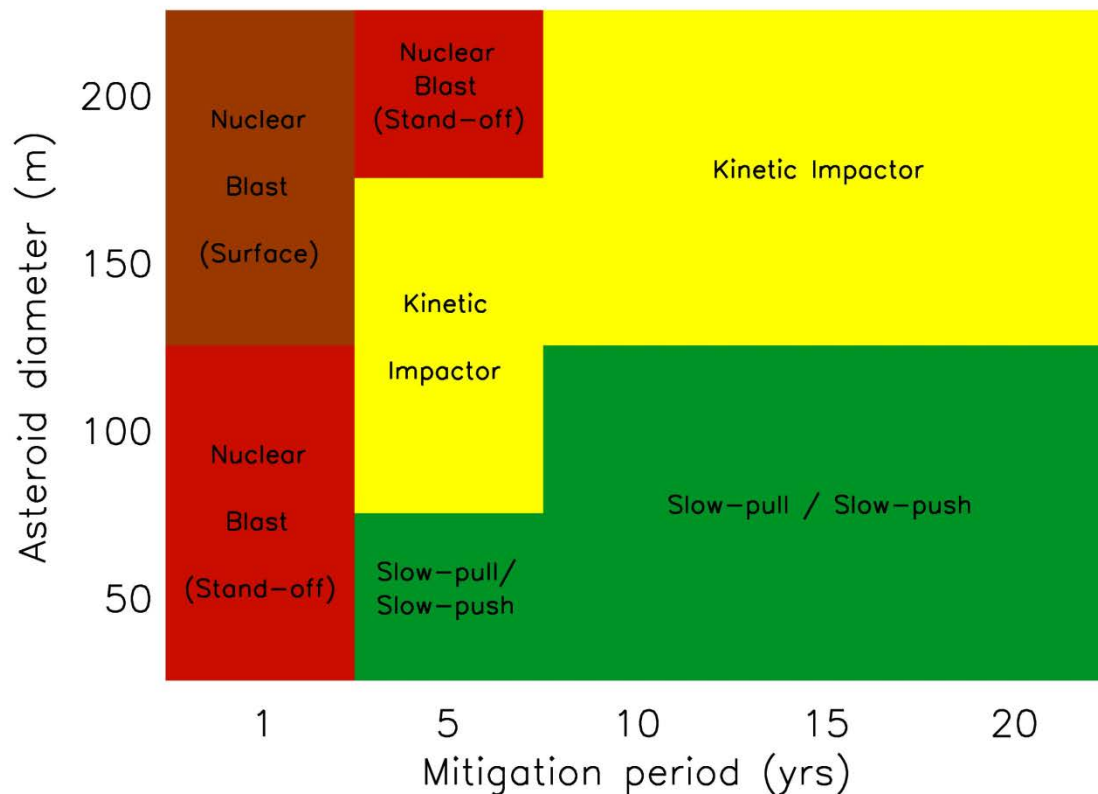


Figure 9. The best choice of space-mission deflection method, according to the results of the NEOShield trade-off study (Deliverable 7.5), is shown for realistic ranges of potential impactor size and time available for deflection of the NEO. "Mitigation period" is defined as the time between the start of the spacecraft's interaction with the asteroid and the predicted date of the impact of the NEO on the Earth. Accurately controllable slow-pull and slow-push techniques include the gravity tractor in addition to alternative approaches studied in less detail within NEOShield, such as the ion-beam shepherd and laser ablation. For very rare threatening NEOs much larger than 200 m, or mitigation periods shorter than a few years, nuclear blast deflection is deemed the best option. For objects smaller than 50 m, no space missions are foreseen, and "civil defence" actions (i.e., sheltering and evacuation measures) would probably be most appropriate. For intermediate scenarios, given current technology, the kinetic impactor appears to be the most viable deflection option. Figure credit: S. Eckersley (NEOShield, Airbus DS Limited, UK) and D. Perna (NEOShield, Observatoire de Paris, LESIA).

Table 1. NEOShield partner organisations

Partner name	Country	Role/main contributions WP = work package involvement (see Table 2)
German Aerospace Center (DLR) Institute of Planetary Research, Berlin	Germany	NEOShield project coordinator; NEO science: data analysis, modeling; global mitigation strategy; public outreach. WP 1, 2, 5, 9, 10
Airbus Defence & Space	Germany	Supervision of technical work; space mission design; public outreach. WP 1, 7, 8, 9, 10
Paris Observatory	France	NEO science: orbital dynamics, space- mission instrumentation; global mitigation strategy. WP 2, 5, 9
Centre National de la Recherche Scientifique (CNRS), Côte d'Azur Observatory	France	NEO science: computer modeling of NEO material and structural properties. WP 2, 3
The Open University	UK	NEO science: all-angle gas-gun experiments. WP 4
Fraunhofer Ernst Mach Institute, Freiburg	Germany	NEO science: horizontal gas-gun experiments, computer modeling of NEO material properties. WP 2, 3, 4
Queen's University Belfast	UK	NEO science: observations, data analysis, deflection test-mission target selection. WP 2, 5
Airbus Defence & Space	UK	NEO deflection techniques trade-off study; global mitigation strategy. WP 7, 8, 9
Airbus Defence & Space	France	Kinetic-impactor concept; space mission design. WP 6, 8
Elecnor Deimos	Spain	Kinetic-impactor concept; space mission design; global mitigation strategy. WP 6, 8, 9
Carl Sagan Center, SETI Institute, Mountain View, California	USA	Gravity tractor concept; space mission design. WP 7, 8, 9
TsNIIMash, Russian Federal Space Agency	Russia	Blast deflection concept; space mission design; global mitigation strategy. WP 7, 8, 9
University of Surrey	UK	Gravity tractor concept. WP 7

Table 2. NEOShield work packages

Work package no.	Description	Type of activity MGT = management RTD = Research/ technological development	Lead partner	Person-months
1	Consortium administrative and financial management.	MGT	DLR	30
2	NEO Physical properties.	RTD	Obs. Paris	76
3	Modelling/numerical simulations.	RTD	CNRS	73
4	Laboratory experiments.	RTD	Open University	57
5	Deflection demonstration mission target NEOs.	RTD	DLR	48
6	Kinetic impactor concept.	RTD	Elecnor Deimos	45
7	Alternative mitigation approaches.	RTD	Airbus DS UK	68
8	Design of appropriate demonstration missions for realistic scenarios.	RTD	Airbus DS Germany	63.5
9	Global response campaign roadmap.	RTD	Obs. Paris	51.5
10	Dissemination of results/Public outreach.	OTHER	DLR	21

Table 3. NEOShield results suggest that the listed NEOs, half of which are categorised as potentially hazardous, are relatively metal rich (from Harris and Drube, 2014, Ap.J. Letters, 785:L4)

THE ASTROPHYSICAL JOURNAL LETTERS, 785:L4 (5pp), 2014 April 10

Table 1
Candidate High Metal Content NEOs Passing the
Filter $0.15 < p_{\text{IR}} \leq 0.3$; $\eta > 2.0$

NEO	Tax.	PHA?	D (km)	p_v	η	η_{err}	p_{IR}
138359		N	1.09	0.10	2.931	0.105	0.19
1865	S	N	1.61	0.14	2.902	0.036	0.27
152931	Q	N	1.65	0.24	2.884	0.138	0.24
152978	S:	Y	0.53	0.11	2.641	0.116	0.19
365071		Y	0.87	0.15	2.559	0.117	0.28
3554	X, M, D	N	3.05	0.09	2.411	0.072	0.19
215442		N	0.79	0.15	2.328	0.325	0.17
152558	S	N	1.36	0.18	2.284	0.051	0.28
366774	AS	Y	0.86	0.20	2.284	0.059	0.29
250680		Y	0.40	0.15	2.279	0.075	0.30
7822	S	Y	1.21	0.13	2.261	0.049	0.30
163243	S, Q	Y	1.68	0.17	2.191	0.061	0.23
263976	L	Y	0.79	0.13	2.165	0.043	0.18
142464		N	0.89	0.12	2.139	0.044	0.22
2002 NW16		N	0.85	0.16	2.118	0.066	0.26
103067	S	Y	1.28	0.25	2.114	0.056	0.29
363024		Y	0.56	0.10	2.055	0.067	0.24
325102		N	0.36	0.12	2.048	0.063	0.18

Notes. Taxonomic classifications are taken from the EARN database (<http://earn.dlr.de/>). A colon following the taxonomic class signifies an uncertain classification. All *WISE* sightings in the catalog, including multiple sightings of the same object, have been considered for the purposes of this table; due to measurement errors or different observational circumstances one record in the *WISE* catalog may pass the filter while another for the same object may not. The uncertainties in values of diameter and albedo derived from NEATM fitting are of the order of 15% and 30%, respectively (Mainzer et al. 2011a; Delbo' et al. 2003). For details of the NEOWISE data see Mainzer et al. (2011a).

NEOShield Final Report: Appendix 1

A Selection of NEOShield Public Outreach Items

Newspapers, internet (selection)

http://www.bbc.co.uk/news/science-environment-16651642	20 Jan. 2012
http://www.allesoversterrenkunde.nl/artikelen/1194-Europa-wil-voorbereid-zijn-als-de-hemel-omlaagvalt.html	21 Jan. 2012
http://www.lefigaro.fr/sciences/2012/01/24/01008-20120124ARTFIG00690-proteger-la-terre-contre-la-chute-d-un-asteroide.php	24 Jan. 2012
http://www.dw-world.de/dw/article/0,,6703710,00.html	25 Jan. 2012
http://www.francetv.fr/info/des-scientifiques-planchent-sur-la-deviation-d-asteroides-au-cas-ou_54551.html	25 Jan. 2012
http://www.spiegel.de/wissenschaft/weltall/0,1518,811368,00.html	26 Jan. 2012
http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10081/151_read-2536/	26 Jan. 2012
http://www.space.com/14370-asteroid-shield-earth-threat-protection-meeting.html	27 Jan. 2012
http://www.sueddeutsche.de/wissen/asteroidenabwehr-vorbild-armageddon-1.1268537	27 Jan. 2012
http://www.dailymail.co.uk/sciencetech/article-2092626/Asteroid-shield-wont-time-19-mile-wide-monster-hurling-past-Earth-week.html	27 Jan. 2012
http://news.yahoo.com/asteroid-threat-earth-sparks-global-neoshield-project-155016535.html	27 Jan. 2012
http://www.mirror.co.uk/news/technology-science/scientists-race-to-build-asteroid-shield-304366	28 Jan. 2012
http://www.nrk.no/vitenskap-og-teknologi/1.7965575	28 Jan. 2012
http://www.francesoir.fr/actualite/scienceecologie/asteroides-des-solutions-a-l-etude-pour-eviter-la-collision-178970.html	29 Jan. 2012
http://www.24heures.ch/savoirs/sciences/Bientot-un-bouclier-antiasteroides-pour-proteger-la-Terre/story/13281508	30 Jan. 2012
http://german.china.org.cn/international/2012-01/30/content_24508259.htm	31 Jan. 2012

http://www.astrium.eads.net/node.php?articleid=8210	31 Jan. 2012
http://www.lexpress.fr/actualite/sciences/comment-detourner-un-asteroide-qui-menace-la-terre_1076349.html	31 Jan. 2012
http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10081/151_read-2640/	3 Feb. 2012
http://www.welt.de/wissenschaft/weltraum/article13849960/NEO-Shield-als-Abwehr-gegen-kosmische-Bomben.html	4 Feb. 2012
http://www.augsburger-allgemeine.de/wissenschaft/Schutzschild-gegen-den-Gott-der-Zerstoeerung-id18634306.html	4 Feb. 2012
http://www.franceinfo.fr/sciences-sante/du-cote-des-etoiles/comment-se-proteger-des-asteroides-511667-2012-02-04	4 Feb. 2012
http://www.raumfahrer.net/news/astronomie/05022012181158.shtml	5 Feb. 2012
http://www.bild.de/news/ausland/asteroiden/forscher-wollen-asteroiden-sprengen-neu-22454458.bild.html	6 Feb. 2012
http://www.rp-online.de/wissen/weltraum/schutzschild-gegen-bomben-aus-dem-all-1.2701621	6 Feb. 2012
http://www.sciencepresse.qc.ca/blogue/2012/02/06/projet-neoshield-pour-ne-finir-dinosaures	6 Feb. 2012
http://www.spacedaily.com/reports/Project_NEOShield_Asteroid_defence_systems_999.html	7 Feb. 2012
http://www.sanfinna.com/?p=52685	7 Feb. 2012
http://www.morgenpost.de/web-wissen/article1903270/Wie-die-Erde-vor-Asteroiden-geschuetzt-werden-soll.html	11 Feb. 2012
http://www.welt.de/print/wams/vermishtes/article13863879/Rettung-vor-dem-grossen-Crash.html	12 Feb. 2012
http://www.universetoday.com/93595/neoshield-a-preemptive-strike-against-asteroids/	15 Feb. 2012
http://www.dw.de/dw/article/0,,15751387,00.html	19 Feb. 2012

<http://www.news.ch/Forscher+Netzwerk+untersucht+Asteroidenabwehr/530515/detail.htm>
21 Feb. 2012

<http://www.rp-online.de/digitales/rp-plus/die-angst-vor-dem-einschlag-1.2733312> 28 Feb. 2012

<http://www.faz.net/aktuell/feuilleton/debatten/asteroidenabwehr-vom-ende-her-11709851.html>
24 Apr. 2012

<http://www.badische-zeitung.de/nachrichten/panorama/die-kosmische-bombe-aus-der-bahn-werfen>
7 Jul. 2012

http://www.oberbipp.ch/documents/NZZ_2.pdf 26 Aug. 2012

<http://www.welt.de/print/wams/article112043724/Davon-geht-die-Welt-nicht-unter.html>
16 Dec. 2012

http://www.washingtonpost.com/national/health-science/nasa-asteroid-fly-by-next-week-closest-ever-of-its-size/2013/02/07/ff47b876-714d-11e2-ac36-3d8d9dcaa2e2_story_1.html 8 Feb. 2013

<http://www.berliner-zeitung.de/raumfahrt/begegnung-im-weltall-asteroid-kommt-der-erde-extrem-nah,10808910,21685052.html> 8 Feb. 2013

<http://www.fr-online.de/raumfahrt/begegnung-im-weltall-asteroid-kommt-der-erde-extrem-nah,1473248,21685052.html> 8 Feb. 2013

<http://www.nzz.ch/wissen/wissenschaft/globale-antworten-auf-eine-globale-bedrohung-1.17997976>
14 Feb. 2013

<http://www.faz.net/aktuell/wissen/weltraum/asteroid-2012-da14-rendezvous-mit-einem-kosmischen-besucher-12080808.html> 15 Feb. 2013

<http://www.faz.net/aktuell/wissen/weltraum/weltraum-forschung-der-asteroidenjaeger-12081900.html> 15 Feb. 2013

[Countless TV, radio, and newspaper reports cited NEOSshield on the occasion of the close approach of 2012 DA14 and the Russian fireball over Chelyabinsk. 15 Feb. 2013]

<http://www.guardian.co.uk/science/across-the-universe/2013/feb/18/asteroids-how-deflect-dangerous>
18 Feb. 2013

<http://www.faz.net/aktuell/wissen/weltraum/interview-ueber-asteroidenabwehr-wenn-sie-uns-zu-nahe-kommen-12085485.html> 20 Feb. 2013

http://www.dw.de/meteorite-explosion-puts-space-on-un-agenda/a-16622302	22 Feb. 2013
http://www.pbs.org/wgbh/nova/next/space/risk-of-an-asteroid-strike/	27 Mar. 2013
http://lci.tf1.fr/science/nouvelles-technologies/risque-d-asteroide-on-est-loin-de-savoir-quoi-faire-et-quelle-decision-7934438.html	23 Apr. 2013
http://www.morgenweb.de/nachrichten/welt-und-wissen/kosmische-bomben-strategien-gegen-eine-todliche-gefahr-1.1131111	25 Jul. 2013
http://www.spiegel.de/wissenschaft/weltall/tscheljabinsk-meteorit-anatomie-einer-beinahe-katastrophe-a-932197.html	6 Nov. 2013
http://www.berliner-zeitung.de/wissen/glueck-im-unglueck-meteorit-von-tscheljabinsk-hatte-gewaltige-wucht,10808894,24921716.html	6 Nov. 2013
http://www.tagesspiegel.de/wissen/asteroiden-sie-koennten-eine-ganzestadt-zerstoeren/9050734.html	9 Nov. 2013
http://www.focus.de/wissen/diverses/wissenschaft-billard-im-all-tests-fuer-asteroiden-abwehr-mit-satelliten_id_3617557.html	15 Feb. 2014
http://www.badische-zeitung.de/nachrichten/panorama/ihn-vorherzusehen-war-unmoeglich--80776323.html	15 Feb. 2014
http://www.morgenpost.de/newsticker/dpa_nt/infoline_nt/wissenschaft_nt/article124881277/Tests-fuer-Asteroiden-Abwehr-mit-Satelliten.html	15 Feb. 2014
http://penzanews.ru/en/opinion/55135-2014	18 Feb. 2014
http://www.esa.int/ger/ESA_in_your_country/Germany/Experten_beraten_ueber_Asteroidenabwehr	18 Feb. 2014
http://www.spiegel.de/wissenschaft/weltall/asteroiden-gefahr-erde-ist-auf-einschlaege-aus-all-schlecht-vorbereitet-a-955924.html	11 Mar. 2014
http://www.focus.de/wissen/weltraum/rettung-a-la-bruce-willis-wie-die-nasa-ein-wirkliches-armageddon-verhindern-will_id_3863144.html	5 Jun. 2014
http://jyllands-posten.dk/nyviden/ECE7021946/forskere-foreslar-atombomber-mod-asteroider/	14 Sep. 2014
http://www.welt.de/wissenschaft/weltraum/article136688570/500-Meter-Koloss-schiesst-nur-knapp-an-Erde-vorbei.html	23 Jan. 2015
http://www.focus.de/wissen/weltraum/schlechte-sicht-aus-deutschland-gigantischer-asteroid-rast-heute-knapp-an-erde-vorbei_id_4430631.html	26 Jan. 2015
http://www.dw.de/asteroid-2004-bl86s-near-miss-with-earth/a-18214901	26 Jan. 2015

<http://en.haberler.com/asteroid-2004-bl86-s-near-miss-with-earth-640000/> 26 Jan. 2015

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<http://www.srf.ch/wissen/natur-umwelt/vorbeigesaut-ein-asteroid-mit-mond-im-gepaeck> 27 Jan. 2015

http://www.francetvinfo.fr/sciences/espace/un-cargo-spatial-hors-de-controle-entame-sa-chute-vers-la-terre_890207.html 29 Apr. 2015

<http://www.tagesspiegel.de/wissen/bedrohung-durch-asteroiden-bei-welcher-groesse-reicht-es-das-gebiet-zu-evakuieren/11910708-3.html> 13 Jun. 2015

Magazine articles

Bild der Wissenschaft, “Kosmische Bomben – die Erde schlägt zurück”, March 2012 (German).

CNRS le journal, “Les astéroïdes – menacent-ils la Terre?”, July-August, 2012 (French).

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NEOShield Final Report: Appendix 2. Tables of Deliverables and Milestones

Del. no.	Deliverable name	Version	WP no.	Lead beneficiary	Nature	Dissemination level	Delivery date from Annex I (proj month)	Actual / Forecast delivery date	Status	Comments
1	Initial progress report to the REA.	1.0	1	DEUTSCHES ZENTRUM FÜR LUFT - UND RAUMFAHRT E V	Report	CO	6	06/07/2012	Submitted	
2	Periodic progress report to the REA.	1.0	1	DEUTSCHES ZENTRUM FÜR LUFT - UND RAUMFAHRT E V	Report	CO	16	30/05/2013	Submitted	
3	Periodic progress report to the REA.	2.0	1	DEUTSCHES ZENTRUM FÜR LUFT - UND RAUMFAHRT E V	Report	CO	32	21/10/2014	Submitted	
4	Final project report to the REA.	1.0	1	DEUTSCHES ZENTRUM FÜR LUFT - UND RAUMFAHRT E V	Report	CO	41	31/05/2015	Submitted	
1	Report on frequency of mitigation-relevant properties.	1.0	2	DEUTSCHES ZENTRUM FÜR LUFT - UND RAUMFAHRT E V	Report	PU	24	10/01/2014	Submitted	
2	requirements for mitigation on precursor reconnaissance.	1.0	2	OBSERVATOIRE DE PARIS	Report	CO	31	08/08/2014	Submitted	
3	Instrumentation designs.	1.0	2	OBSERVATOIRE DE PARIS	Report	CO	24	10/01/2014	Submitted	
4	Requirements modelling/simulation work and lab. experiments.	1.0	2	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE	Report	CO	2	21/03/2012	Submitted	

1	Experiments requirements.	1.0	3	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE	Report	CO	5	03/07/2012	Submitted	
2	Modeling/simulations of laboratory results.	1.0	3	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE	Report	CO	24	13/01/2014	Submitted	
3	Scaled-up modelling: momentum gain and NEO deflection efficiency.	2.0	3	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE	Report	CO	31	19/05/2015	Submitted	
4	Potential for re-accumulation of hazardous large bodies from impact ejecta.	2.0	3	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE	Report	PU	31	05/06/2015	Submitted	
1	Results of momentum-transfer experiments on unconsolidated materials.	2.0	4	THE OPEN UNIVERSITY	Report	CO	27	09/06/2015	Submitted	
2	Material properties of the regolith analogue samples.	1.0	4	FRAUNHOFER-GESELLSCHAFT ZUR FÖRDERUNG DER ANGEWANDTEN FORSCHUNG E.V	Report	CO	12	28/06/2013	Submitted	
3	Results of impact experiments on consolidated samples.	1.0	4	FRAUNHOFER-GESELLSCHAFT ZUR FÖRDERUNG DER ANGEWANDTEN FORSCHUNG E.V	Report	CO	27	10/04/2014	Submitted	
1	Dynam.- and phys.-property requirements for NEOs as targets in mitigation demo missions.	1.0	5	DEUTSCHES ZENTRUM FÜR LUFT - UND RAUMFAHRT E.V	Report	CO	15	21/05/2013	Submitted	
2	List of potential target NEOs and their properties relevant to mitigation demo missions.	1.0	5	THE QUEEN'S UNIVERSITY OF BELFAST	Report	PU	11	10/12/2012	Submitted	

3	Prioritized demo-mission target suggestions.	1.0	5	THE QUEEN'S UNIVERSITY OF BELFAST	Report	PU	15	31/05/2013	Submitted	
4	Orbit refinement and reconnaissance observations as required.	1.0	5	THE QUEEN'S UNIVERSITY OF BELFAST	Report	PU	31	18/09/2014	Submitted	
1	Significant open issues with regard to the kinetic-impactor concept.	1.0	6	DEIMOS SPACE SOCIEDAD LIMITADA UNIPERSONAL	Report	CO	5	18/06/2012	Submitted	
2	Impactor GNC technologies.	1.0	6	AIRBUS DEFENCE AND SPACE SAS	Report	RE	31	22/09/2014	Submitted	
3	Orbitor GNC technologies.	2.0	6	DEIMOS SPACE SOCIEDAD LIMITADA UNIPERSONAL	Report	CO	31	21/01/2015	Submitted	
1	Assessment of gravity tractor and other mitigation concepts.	1.0	7	SETI INSTITUTE CORPORATION	Report	PU	15	06/05/2013	Submitted	
2	Assessment of gravity tractor with multiple-spacecraft tractors.	1.0	7	UNIVERSITY OF SURREY	Report	PU	15	22/05/2013	Submitted	
3	Assessment of blast deflection and other mitigation concepts.	3.0	7	FEDERALNOE GOSUDARSTVENNOE UNITARNOPREDPRIYATIE TSENTRALNY NAUCHNO-ISLEDovATELSKY INSTITUT MACHINOSTROENIYA	Report	PU	15	05/05/2014	Submitted	
4	Potential benefits of human missions for mitigation strategies.	1.0	7	AIRBUS DSGMBH	Report	PU	15	03/04/2013	Submitted	
5	Trade-offs of viable alternative mitigation concepts.	1.0	7	AIRBUS DEFENCE AND SPACE LTD	Report	PU	18	24/09/2013	Submitted	
1	Requirements on NEO target	1.0	8	AIRBUS DSG	Report	PU	4	28/06/2012	Submitted	

	rget selection.			GMBH						
2	Detailed demo-mission design, kinetic impactor.	1.0	8	AIRBUS DS GMBH	Report	CO	36	25/02/2015	Submitted	
3	Detailed demo-mission design, gravity tractor.	1.0	8	SETI INSTITUTE CORPORATION	Report	CO	36	29/05/2015	Submitted	
4	Detailed demo-mission design, blast deflection.	1.0	8	FEDERALNOE GOSUDARSTVENNOE UNITARNOPREDPRIYATIE TSENTRALNY NAUCHNO-ISLEDOVATELSKY INSTITUT MACHINOSTROENIYA	Report	CO	36	16/03/2015	Submitted	
5	Assessment of demo-mission variants.	1.0	8	AIRBUS DEFENCE AND SPACE LTD	Report	PU	36	07/04/2015	Submitted	
1	Preliminary roadmap outline.	1.0	9	OBSERVATOIRE DE PARIS	Report	CO	31	08/08/2014	Submitted	
2	Required reconnaissance observations.	1.0	9	OBSERVATOIRE DE PARIS	Report	PU	36	08/06/2015	Submitted	
3	Description of decision-making tool.	1.0	9	DEIMOS SPACE SOCIEDAD LIMITADA UNIPERSONAL	Report	CO	36	19/01/2015	Submitted	
4	Atmospheric trajectory analysis and ground damage limitation.	1.0	9	FEDERALNOE GOSUDARSTVENNOE UNITARNOPREDPRIYATIE TSENTRALNY NAUCHNO-ISLEDOVATELSKY INSTITUT MACHINOSTROENIYA	Report	PU	31	18/09/2014	Submitted	
5	Final roadmap, including political decision-making	1.0	9	AIRBUS DEFENCE AND S	Report	PU	36	24/04/2015	Submitted	

	, reconnaissance, decision tool.			PACE LTD						
6	Options for future implementation of proposed demo missions.	1.0	9	AIRBUS DS GMBH	Report	CO	41	31/05/2015	Submitted	
1	Presentation of web designs to project.	1.0	10	AIRBUS DS GMBH	Report	CO	3	30/04/2013	Submitted	
2	Public web site online.	1.0	10	AIRBUS DS GMBH	Other	PU	6	29/05/2015	Submitted	
3	Project web site.	1.0	10	AIRBUS DS GMBH	Other	CO	6	29/05/2015	Submitted	
4	Outreach events.	1.0	10	DEUTSCHES ZENTRUM FÜR LUFT- UND RAUMFAHRT E V	Other	PU	41	27/05/2015	Submitted	

Milestones

Milestone no.	Milestone name	Work package no	Lead beneficiary	Delivery date from Annex I	Achieved Yes/No	Actual / Forecast achievement date	Comments
1	Kick-Off meeting.	All	DLR	16/01/2012	Yes	16/01/2012	
2	Initial progress assessment.	1,2,3,4,5,6,7,8,10	DLR	31/05/2012	Yes	31/05/2012	
3	Preparation for mission designs complete.	1,2,4,5,6,7	DLR	31/03/2013	Yes	30/06/2013	Delays in submission of some deliverables have only minor impact on overall schedule.
4	Outline designs of demo missions complete.	1,2,3,4,7,8	Astrium-DE	31/12/2013	Yes	31/12/2013	
5	Research work packages wrap up.	1,2,3,4,5,6,9	DLR	31/07/2014	Yes	31/07/2014	Delays in submission of some deliverables have only minor impact on overall schedule.
6	Final presentation.	All	DLR	31/05/2015	Yes	25/06/2015	